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Magnesium Sulfate, Grain or Alfalfa Hay as Sources of Magnesium to Calves Fed Whole Milk 1/

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Whole milk supplemented with trace minerals and vitamin D has been shown to produce hypomagnesemia and death in young calves. Addition of magnesium salts to milk to furnish a magnesium intake of over 2.0 gm. per cwt. has been found necessary to prevent hypomagnesemia in young rapidly growing calves (1, 2, 3). Other diets, low in magnesium but devoid of milk, have maintained normal plasma magnesium levels on much lower magnesium intakes but have produced somewhat slower rates of growth (4, 5). Certain experiments have indicated that the need for dietary magnesium of milk fed calves was less when the diet included natural feedstuffs than when it included inorganic magnesium salts (6, 7).

Information obtained from a preliminary trial performed at Beltsville also indicated that magnesium from a grain mixture or alfalfa hay was somewhat better utilized than magnesium from inorganic sources when fed in addition to whole milk. These data are shown in table 1.

It can be noted that serum and bone magnesium levels more nearly approximated normal values when a grain mixture or alfalfa hay furnished a portion of the magnesium than when it was furnished by inorganic magnesium or alfalfa ash. Calves on usual rations have serum magnesium concentrations of over 2.0 mg. % and bone ash magnesium concentrations of 1.0%. Calves fed corn meal refused to eat it and their performance was similar to calves receiving milk only. The addition of potassium did not improve the utilization of magnesium and it appears unlikely that the increased potassium intake when hay and grain are fed was responsible for the increased magnesium utilization.

With this preliminary information an experiment was performed to more adequately test differences in magnesium utilization between three dietary sources. In this experiment the calves were all brought into a mild state of magnesium deprivation by feeding only whole milk (plus trace minerals and vitamin D) until serum magnesium concentration decreased to below 2 mg. %. At this time additional magnesium was fed in the form of $MgSO_4$, alfalfa

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hay or grain to make a total intake of 1.0 gram Mg per one hundred pounds body weight (cwt). One-half of the calculated magnesium intake was from milk and the other half from the supplement. Each dietary supplement group consisted of four animals making a total of 12 animals in the experiment. Within each dietary supplement group, 2 animals were of the Holstein breed and 2 of the Jersey breed and within each breed and supplemental group half of the animals received additional alpha-tocopherol by capsule.

The age at which it became necessary to add the magnesium supplement ranged from 49 to 131 days for individual calves and from 77 to 88 days for the average of the three dietary groups (table 2).

Calves receiving either the grain or the hay supplement gained body weight at a faster rate than did the calves on $MgSO_4$ supplement (table 2). The Holstein calves gained faster than the Jersey calves ($P > 0.01$). An analysis of variance on monthly body weights or total gains showed no differences of statistical significance that were due to type of magnesium supplement, tocopherol feeding or interaction between these two dietary additions.

Average serum magnesium concentrations for the three groups at constant intervals before and after addition of the magnesium supplement are shown in figure 1.

Serum magnesium values increased more rapidly and to a slightly greater extent when $MgSO_4$ was added to the diet of the partially depleted calves than when grain or hay was added to the diet to furnish half the dietary magnesium. The values actually remained at or near normal concentrations from 1 to 3 months after the addition of the supplement. After this time the values for all three groups declined to below normal concentrations. The $MgSO_4$ supplemented calves had a larger and more rapid decrease in serum magnesium concentrations than did calves receiving grain or hay. Values for each individual calf are given in table 2. There were large variations among calves in each group for level of serum magnesium (table 3) and in the extent of its decrease. Because of this and the small number of animals employed, differences due to dietary treatments in the decrease or monthly serum magnesium values were not sufficient to attain statistical significance. The final level of serum magnesium was higher for the grain and hay fed calves than for those receiving $MgSO_4$.

Bone magnesium at biopsy and at termination of experiment are given in table 3. Also presented are age and days on supplement, Mg intake and serum levels for the preceding month and ratio of bone magnesium per unit of intake. There was a tendency for the calves fed grain and especially those fed hay to have higher magnesium values at biopsy and at the termination of the experiment. Differences between breeds were also noted. However, an analysis of variances indicated that none of these differences were significant. The intake for calves supplemented with $MgSO_4$ was somewhat higher than those supplemented with

hay which in turn were higher than those supplemented with grain (table 2). These non-significant differences were due to feed refusals. Thus, when the ratio of bone magnesium to magnesium intake was calculated and analysed the differences between dietary treatments and between breeds becomes larger than when expressed on actual magnesium content. For instance, the magnesium content of rib ends at termination was 0.40% for $MgSO_4$ and 0.54 for hay fed animals (a ratio of 1.0 to 1.34). However, when expressed in relation to intake, the values were were 0.52 and 1.00 (a ratio of 1.0 to 1.93). On this basis these data could be interpreted as indicating that the calves fed hay and grain were somewhat more efficient in their utilization of dietary magnesium and similarly, the Holstein calves were somewhat more efficient in their utilization of dietary magnesium than Jersey calves. However, even these differences were not statistically significant.

The level of dietary magnesium used in these trials was not sufficient to maintain normal concentrations of magnesium in blood serum and bone. With these diets .8 to .9 gram magnesium per cwt was insufficient to meet dietary requirements when the observation period was extended for several months. English investigators have stated the magnesium requirement of milk fed calves was about .7 gram/cwt based on maintenance of serum magnesium values in trials of about 90 days in length. The serum magnesium values in the trial shown in figure 1 were maintained approximately at normal levels for 3 months yet when the calves were continued on this level of intake (.8 to .9 gm/cwt) a magnesium deficiency occurred. Evidently it is possible to have blood magnesium concentrations remain at near normal levels while bone magnesium concentrations decrease gradually during the early phases of such experiments.

At termination of the experiment some calves in all three groups had grossly calcified areas in the heart and/or arteries and those given additional tocopherol had as great an incidence as those not given tocopherol. The presence of metastatic calcification in heart and great vessels appears to be a specific pathalogical change due to a prolonged subminimal intake of magnesium and is not due to other causes such as tocopherol deficiency as is the contention of other investigators (8, 9).

Summary:

Using a whole milk basic ration, an experiment was performed to determine if there were differences in the utilization of magnesium from magnesium sulfate, grain or alfalfa hay when used as a supplement to milk. Magnesium supplied in these diets approximated 1.0 gm/100 lb. body weight. Serum magnesium and bone magnesium decreased during the trial with all three supplements indicating that this level of magnesium intake was insufficient to meet requirements. In this study there were no differences of statistical significance in body weight, level of serum magnesium, or its decrease, level of magnesium intake or in magnesium content of bone ash due to the dietary source of magnesium. The extent of the individual variation and the small ~~tocopherol~~

number of calves used caused the differences found in favor of hay and grain to be statistically insignificant.

There was a tendency for the Holstein calves to have higher serum magnesium concentrations, a lower decrease in concentration during the trial, a higher concentration of magnesium in bone ash and a higher ratio of bone magnesium to dietary magnesium or efficiency of magnesium utilization than found in Jersey calves.

There was a tendency for calves supplemented with magnesium sulfate to have lower serum magnesium concentrations, larger decrease in concentration in serum and in bone during the trial, a lower concentration of magnesium in the bone ash, and a lower bone magnesium to dietary magnesium ratio than calves supplemented with equivalent amounts of magnesium in the form of grain or hay. The results indicate a possible reduced utilization of inorganic magnesium when compared to usual feeds when used to supplement milk diets. However, since the differences lacked statistical significance a more definite statement should not be made and it appears likely that factors other than its source affect magnesium utilization in milk fed calves.

Metastatic calcification was found in the heart and great vessels. These pathological changes appeared to be due to the prolonged subminimal intake of Mg and the incidence of these changes was not affected by source of Mg or by addition of tocopherol to the ration.

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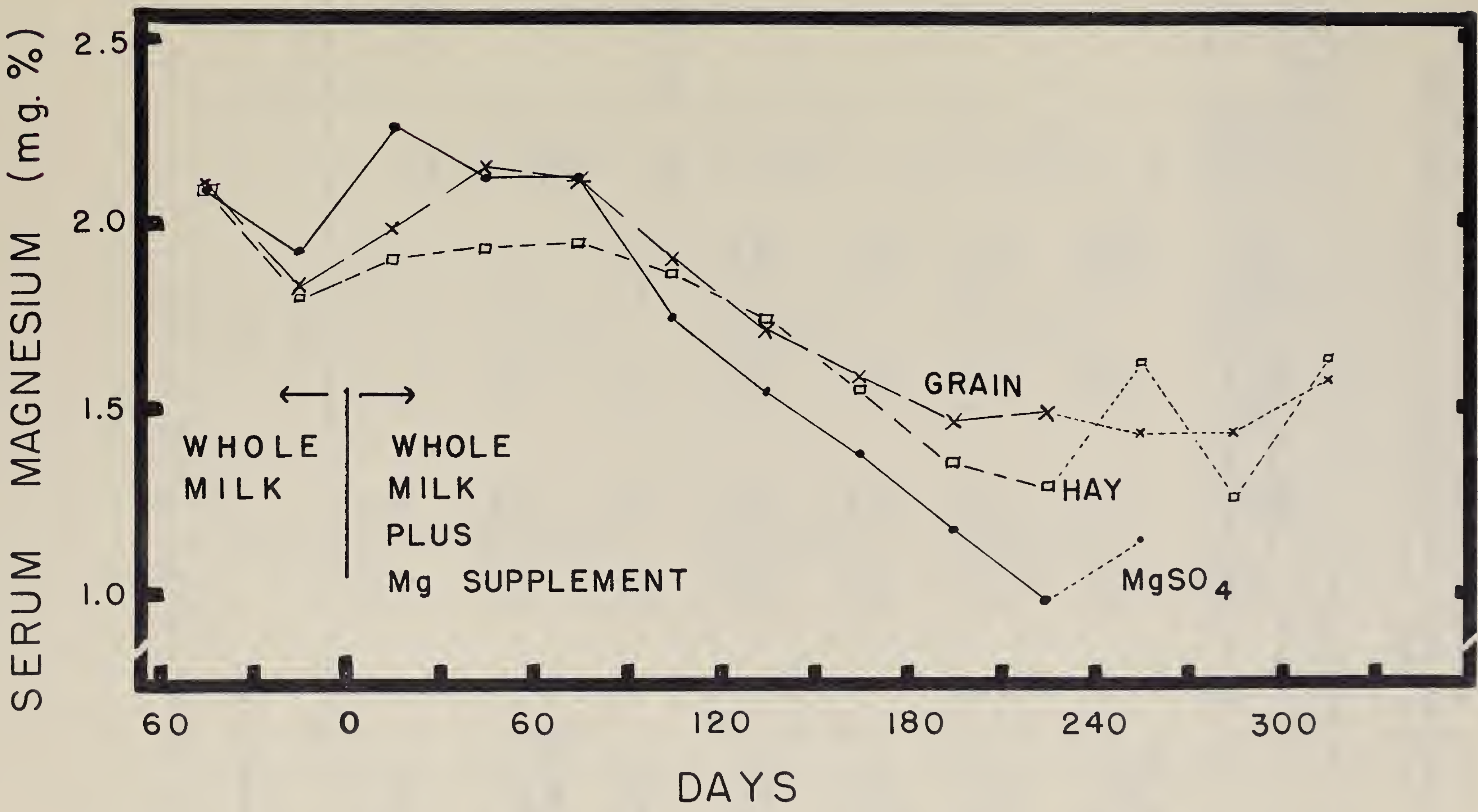

Figure 1 - Average serum magnesium concentrations for calves fed equal levels of magnesium from milk plus grain, hay or $MgSO_4$. Dotted lines after 240 days on milk plus supplement represent only 2 to 3 calves per group, others represent 4 calves per group.

Table 1 - Total magnesium intake and concentration of magnesium in blood serum and bone ash of calves on milk plus various supplements (preliminary trial)

Supplement	No. of calves	Age interval (month) 3-5	6-9	10-12	13-15	Calves Died	Calcified Heart score	Mg in rib-end ash
						%	sq.cm.	%
Alfalfa hay plus Mg SO_4	2					50	0	.87
Mg intake (gm/cwt/day)		1.6	1.1	1.0	1.5[a]			
Serum Mg conc. (mg. %)		2.3	2.2	1.8	2.0[a]			
Alfalfa Hay	2					50	0	.68
Mg intake (gm/cwt/day)		2.0[b]	.9	.8	1.0[b]			
Serum Mg conc. (mg. %)		1.9	1.6	1.7	2.2			
Ash of Alfalfa Hay	2					50	0	.37
Mg intake (gm/cwt/day)		1.6	1.0	1.1[b]	1.1[b]			
Serum Mg conc. (mg.%)		2.2	2.0	1.5	1.4			
Grain Mixture	3					33	0	.71
Mg intake (gm/cwt/day)		1.1	.8	.7	.5[a]			
Serum Mg conc. (mg. %)		2.0	2.2	2.0	2.0[a]			
Corn meal	4					100	1.4	---
Mg intake (gm/cwt/day)		.8	.6	---	---			
Serum Mg conc. (mg. %)		1.9	1.4	---	---			
Mg SO_4, Mg CO_3, or Mg Ac	19					100	.2	.51
Mg intake (gm/cwt/day)		1.0	1.0	.9	---			
Serum Mg conc. (mg. %)		2.1	1.6	1.1	---			
Mg SO_4 plus K Ac	3					100	.5	.41
Mg intake (gm/cwt/day)		1.1	1.0	---	---			
Serum Mg conc. (mg. %)		2.2	1.2	---	---			

a/ One calf only.

b/ Some Mg SO_4 added also.

Table 2 - Miscellaneous data on calves fed three sources of magnesium

Calf no. and breed	toco-pherol	Age Mg Supple-ment started	Body Wt. gain dur-ing next 7 mo.	Mg. intake during next 7 months	Decrease in Serum Mg conc.[a]	Calcifi-cation in heart and arteries	Terminal Serum tocopher-ol
		(days)	(lb/day/calf)	(gm/cwt/day)	(Mg. %)	(sq.cm.)	(mg. %)
Mg SO_4							
1169J	+	63	.84	.97	1.71	1.0	.31
3700J	-	131	1.77	.84	.46	0	.22
1302H	+	83	2.03	.91	1.10	2.0	.07
1306H	-	55	1.61	.92	1.20	0	.04
		83	1.56	.91	1.12		
Grain							
1168J	+	75	1.32	.81	.33	1.5	.45
1177J	-	100	1.32	.79	.67	.7	.18
1304H	+	74	2.20	.62	1.20	2.0	.32
3531H	-	58	2.82	.79	.20	0	.16
		77	1.91	.75	.60		
Alfalfa Hay							
1178J	+	51	.85	.83	1.01	.5	.34
1174J	-	126	.70	.86	1.13	3.0	.18
3528H	+	49	2.45	.82	+ .07	0	.19
1311H	-	127	2.99	.68	.30	.2	.14
		88	1.75	.80	.59		
Average Jersey		91	1.13	.85	.89	1.1	.28
Average Holstein		74	2.35	.79	.66	.7	.15
Average + tocopherol--			1.62	.83	.88	1.1	.28
Average - tocopherol--			1.87	.81	.66	.7	.15

a/ Average value 0-60 days after initiating supplement minus average value 180-240 days after initiating supplement.

Table 3 - Magnesium in rib biopsy and rib ends with intake and serum values for the preceding 30 days

Group and calf no.	Age at biopsy	on supple-ment	Mg in rib bone biopsy	Serum Mg 0-30 days prior	Mg in-take 0-30 days prior	Mg ratio bone intake	Type of death	Age at death	on supple-ment	Mg in rib end at death	Serum Mg 0-30 days prior	Mg in-take 0-30 days prior	Mg ratio bone ÷ intake
	(days)	(days)	% ash	mg %	gm/cwt/day			(days)	(days)	% ash	mg %	gm/cwt/day	
Mg SO_4													
1169	240	177	0.75	1.16	1.10	0.68	N	283	220	0.25	0.61	0.96	0.26
3700	240	109	0.78	1.72	0.86	0.91	S	467	336	0.62	1.22	0.63	0.98
"	276[a/]	145	0.76	1.85	0.91	0.84							
1302	240	157	0.51	1.58	0.91	0.56	S	335	252	0.28	1.04	0.83	0.34
1306	240	185	0.51	1.25	0.91	0.56	N	280	225	0.44	1.42	0.91	0.48
ave	240	157	0.66	1.51	0.94	0.68		341	258	0.40	1.07	0.83	0.52
Grain													
1168	240	165	0.56	1.93	0.77	0.73	N	429	354	0.51	0.77	0.57	0.90
1177	240	140	0.51	1.09	0.91	0.56	N	291	191	0.26	0.73	0.81	0.32
1304	240	166	0.73	1.62	0.53	1.38	S	411	337	0.46	0.98	0.43	1.07
3531	241	182	0.88	2.03	0.70	1.26	S	374	316	0.94	2.46	0.55	1.71
ave	240	163	0.67	1.67	0.73	0.98		376	300	0.54	1.24	0.59	1.00
Alf. Hay													
1178	240	189	0.64	1.54	0.85	0.75	S	446	395	0.63	1.43	0.83	0.76
1174	240	114	0.67	1.67	0.95	0.71	N	370	244	0.52	0.76	0.81	0.64
"	270[a/]	144	0.77	1.72	0.97	0.79							
3528	240	191	0.83	1.65	0.85	0.98	S	451	402	0.78	1.92	0.55	1.42
"	343[a/]	294	0.77	1.62	0.79	0.97							
1311	253	126	0.80	1.80	0.82	0.98	S	362	235	0.83	1.56	0.59	1.41
ave	240	155	0.75	1.67	0.87	0.85		407	319	0.69	1.42	0.70	1.06
Average Jersey			.65	1.51	.91	.72		381	290	.47	.92	.77	.64
" Holstein			.71	1.65	.79	.95		369	295	.62	1.56	.64	1.07
" + tocopherol			.67	1.58	.83	.85		---	---	.48	1.13	.70	.79
" - tocopherol			.69	1.59	.86	.83		---	---	.60	1.36	.72	.92

a/ Second rib biopsy taken at indicated ages, not included in average or analysis of variance.
N- Natural death. S - Slaughtered.